ROYAL METEOROLOGICAL SOCIETY: AUSTRALIAN BRANCH

Chairman's Address: 15 November 1977

THE FIRST GARP GLOBAL EXPERIMENT

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ABSTRACT

The First GARP Global Experiment (FGGE) is the largest and most complex observational experiment within the Global Atmospheric Research Programme (GARP), a joint research undertaking of the World Meteorological Organization and the International Council of Scientific Unions. For a period of twelve months starting on 1 December 1978, the entire global atmosphere will be studied in unprecedented detail through the use of a composite observing system involving satellites, ships, aircraft, balloons, and ocean buoys in addition to the routine observing system of the World Weather Watch. The data will be collected and processed through a special FGGE data management scheme involving the combined efforts of many countries and international organisations. Within two years of the completion of the observational phase of the experiment, the complete global sets of meteorological and oceanographic data should be available for research aimed at improving the range and accuracy of weather forecasting and obtaining a better understanding of the physical basis of climate.

INTRODUCTION

After a decade of planning, the Global Weather Experiment FGGE (an acronym for 'First GARP Global Experiment') formally began on 1 December 1977 with the commencement of a build-up year. For a period of twelve months starting on 1 December 1978, the entire global atmosphere will be monitored with an array of satellites, ships, instrumented aircraft, constant level balloons, drifting buoys, and other observing systems in a detail that has never been possible before. The FGGE will be the largest fully international experiment ever undertaken in meteorology and possibly in all science. It is the major observational effort of the Global Atmospheric Research Programme (GARP), which has the ultimate goal of a scientifically sound basis for long range weather prediction. The planning for FGGE has involved the efforts of many thousands of scientists and administrators from virtually every country of the world. It represents a direct international investment of several hundreds of millions of dollars and a total investment of the order of a thousand million dollars. It is premised on the belief that the potential benefits of improved weather prediction and better understanding of the mechanisms of climate variation far outweigh the cost of the experiment and the risks of failure. The

* Edited summary.
purpose of this paper is to give a simple overview of the origin, objectives, and planning of FGGE as it entered its build-up year.

THE GLOBAL ATMOSPHERIC RESEARCH PROGRAMME

The concept of GARP had its origins in the exciting technological developments of the Sputnik period. The successful launching of instrumented earth-orbiting satellites in the late 1950s opened up the prospect of monitoring the world's weather patterns from space. The development of computers made possible the numerical simulation of the atmospheric circulation through physical/mathematical models and thus pointed the way to a feasible scientific basis for weather forecasting.

In September 1961 US President J.F. Kennedy addressed the General Assembly of the United Nations. He said:

With modern computers, rockets and satellites, the time is ripe to harness a variety of disciplines for a concerted attack . . . the atmospheric sciences require world-wide observation and, hence, international cooperation . . . We shall propose further cooperative efforts between all nations in weather prediction . . . We shall propose, finally, a global system of . . . satellites linking the whole world . . .

The nations of the world took up the challenge. In General Assembly Resolution 1721(XVI) of 20 December 1961, the United Nations acknowledged the potential value of improved meteorological services to mankind and pointed the way ahead:

The General Assembly

Noting with gratification the marked progress for meteorological science and technology opened up by the advances in outer space,

Convinced of the world-wide benefits to be derived from international co-operation in weather research and analysis,

1. Recommends to all Member States and to the World Meteorological Organization . . . the early and comprehensive study, in the light of developments in outer space, of measures:

   (a) To advance the state of atmospheric science and technology so as to provide greater knowledge of basic physical forces affecting climate . . .

   (b) To develop existing weather forecasting capabilities and to help Member States make effective use of such capabilities through regional meteorological centres;

2. Requests the World Meteorological Organization, consulting . . . with Unesco and other specialised agencies and governmental and non-governmental organisations, such as the International Council of Scientific Unions, to submit a report to its member Governments and to the Economic and Social Council . . . regarding appropriate organizational and financial arrangements to achieve these ends . . .

Developments came thick and fast (Fig 1). In response to Resolution 1721 (XVI), the World Meteorological Organization submitted its 'First Report on the Advancement of the Atmospheric Sciences and their Applications in the Light of Developments in Outer Space' and, in its Resolution 1802 (XVII) of 14 December 1962, the UN General Assembly issued a new call for global cooperation in meteorological operations and research. This time the General Assembly specifically invited the International Council of Scientific Unions to join in a concerted effort in the following terms:
The General Assembly

1. Notes with appreciation the prompt initial response of the World Meteorological Organization . . . ;

2. Calls upon Member States to strengthen weather forecasting services and to encourage their scientific communities to cooperate in the expansion of atmospheric science research;

3. Recommends that the World Meteorological Organization . . . should develop in greater detail its plan for an expanded programme to strengthen meteorological services and research, placing particular emphasis on the use of meteorological satellites . . . ;

4. Invites the International Council of Scientific Unions . . . to develop an expanded programme of atmospheric science research which will complement the programmes fostered by the World Meteorological Organization.

By late 1967 two parallel developments of immense significance to the future of global cooperation in meteorology had taken place. In April 1967 the Fifth World Meteorological Congress approved the initial four-year plan and implementation program for the World Weather Watch, an integrated global observing, communications, and data processing system designed to make available to every nation the meteorological and related environmental information required in order to enjoy the most efficient and effective meteorological services possible (World Meteorological Organization 1967). On 10 October 1967 the World Meteorological Organization, as a specialised agency of the United Nations with membership including virtually every nation of the world, and the non-governmental International Council of Scientific Unions agreed to sponsor jointly a Global Atmospheric Research Programme as the international framework for the development of a scientifically sound physical basis for long range weather prediction.

As subsequently defined and agreed by WMO and ICSU:

The Global Atmospheric Research Programme (GARP) is a programme for studying those physical processes in the troposphere and stratosphere that are essential for an understanding of:

(a) The transient behaviour of the atmosphere as manifested in the large-scale fluctuations which control changes of the weather; this would lead to increasing the accuracy of forecasting over periods from one day to several weeks;

(b) The factors that determine the statistical properties of the general circulation of the atmosphere which would lead to a better understanding of the physical basis of climate.

This programme consists of two distinct parts, which are, however, closely interrelated:

(i) The design and testing by computational methods of a series of theoretical models of relevant aspects of the atmosphere's behaviour to permit an increasingly precise description of the significant physical processes and their interactions;

(ii) Observational and experimental studies of the atmosphere to provide the data required for the design of such theoretical models and the testing of their validity.
Fig 1  Origin of the World Weather Watch (WWW) and the Global Atmospheric Research Programme (GARP) as parallel developments from United Nations General Assembly Resolution 1721 (XVI) of 20 December 1961.
GLOBAL ATMOSPHERIC RESEARCH PROGRAMME

ULTIMATE GOAL
A SCIENTIFICALLY SOUND PHYSICAL BASIS FOR LONG-RANGE WEATHER PREDICTION

MAIN OBJECTIVES OF GARP
IMPROVED UNDERSTANDING OF THE PHYSICAL PROCESSES OF THE GENERAL CIRCULATION
FORMULATION OF IMPROVED PHYSICAL MODELS OF THE ATMOSPHERE
OPTIMUM DESIGN FOR A GLOBAL OBSERVING SYSTEM

GARP SUB-PROGRAMMES
GLOBAL SUB-PROGRAMME
NUMERICAL EXPERIMENTATION SUB-PROGRAMME
CLIMATE DYNAMICS SUB-PROGRAMME
TROPICAL SUB-PROGRAMME
POLAR SUB-PROGRAMME
MONSOON SUB-PROGRAMME
AIR-SURFACE INTERACTION SUB-PROGRAMME
RADIATION SUB-PROGRAMME
MOUNTAIN SUB-PROGRAMME
FGGE 1977-79
GATE 1974
POLEX 1979
ISME 1973; MONSOON 77; MONEX, WAMEX 1979
AMTEX 1974-75; JASIN 1970-78
CAENEX 1970-75
ALPEX 1980

MAIN POTENTIAL BENEFITS
INCREASED ACCURACY OF FORECASTING OVER PERIODS FROM ONE DAY TO SEVERAL WEEKS (GARP "FIRST OBJECTIVE")

Fig 2 A summary interpretation of the ultimate goal and objectives of GARP leading to the formulation and execution of a number of GARP Sub-programmes and associated observational experiments (centre right) and eventual realisation of benefits in the fields of forecasting and climate.
As the main scientific organ for the planning and organising of the research program, WMO and ICSU set up a Joint Organizing Committee of twelve distinguished scientists chaired by Professor B. Bolin of Sweden. The two organisations also agreed on procedures for the establishment of GARP Sub-programmes and subsidiary bodies and for the conduct of GARP Experiments (Joint Organizing Committee 1969a). Figure 2 summarises the main Sub-programmes and corresponding field experiments so far undertaken or planned under GARP.

CONCEPT OF A GLOBAL WEATHER EXPERIMENT

The concept of a global observational experiment has been central to the planning of GARP from the outset. Even before the formal conclusion of the WMO-ICSU agreement in 1967, the outlines of such an experiment were beginning to take shape (National Academy of Sciences 1966). By the mid-1960s it had become clear that further progress with the development of physical/mathematical models for simulation and forecasting of the large-scale atmospheric circulation would depend on a much better cover of observational data than was then available or could be expected to become available from the operational World Weather Watch. The FGGE was thus conceived as an internationally coordinated effort to measure the large-scale state and motion of the entire global atmosphere over an extended period (Joint Organizing Committee 1969b, Bolin 1971, Joint Organizing Committee 1973).

In view of the rapid advances in space and computer technology that had inspired and followed from the UN resolutions of 1961 and 1962, it appeared, in the early stages of planning for GARP, that an adequate global observing system and sufficiently powerful computers to process the data it would provide could be achieved by the mid 1970s (Bolin 1969). It was recognised that the planning would involve many difficult scientific decisions and value judgments and would, in the end, represent a balance between three basic factors - scientific objectives, technological feasibility, and availability of resources. A major milestone was passed in September 1972 when, at an Intergovernmental Conference in Geneva, the nations agreed that the concept of a global experiment remained valid and that, despite gathering clouds on the economic horizon, detailed planning for the conduct of the FGGE should proceed (World Meteorological Organization 1972). Institutional responsibility for implementation of the Experiment was assigned to WMO and hence to the National Meteorological Services of the world and a high-level Intergovernmental Panel was set up under the auspices of the WMO Executive Committee to serve as the international focus for the detailed coordination, planning, and implementation of the FGGE (World Meteorological Organization 1973). By February 1976 international plans and commitments had reached the stage where the build-up year of the FGGE could be firmly scheduled to begin in late 1977 with the operational year of intensive global observations starting at the end of 1978.

The central task of the Global Weather Experiment is to obtain a data set that will be both adequate as a basis for global numerical weather prediction research and feasible in terms of technology and resources (World Meteorological Organization 1977a). Although initially conceived as the first (First GARP Global Experiment) of a number of such global experiments, it is now fairly widely accepted that an undertaking of the scale of FGGE could not be mounted again for many years. The FGGE data set must thus be such as to serve, as far as possible, the global data requirements under GARP, including those associated with general circulation research and climate modelling. With this in mind, the specific goals of FGGE have been identified as follows:

1. to obtain a better diagnostic understanding of the large-scale dynamics of the atmosphere and of critical physical processes;
2. to provide initial and verifying conditions for modelling experiments designed to extend the range of operational weather prediction towards its ultimate limits;

3. to guide the design of an optimum meteorological observing and prediction system for operational weather prediction that will employ on a continuing basis the technical and scientific knowledge in the Experiment;

4. to investigate, within the limitation of a one-year period of observation, the physical mechanisms underlying fluctuations of climate in the time range of a few weeks to a few years and to develop and test appropriate climatic models.

THE DESIGN OF THE EXPERIMENT

The design and planning of the Global Weather Experiment has been an iterative process involving experts from many disciplines in a variety of supporting studies and systems developments over more than a decade. The GARP Study Conference at Skepparholmen near Stockholm in 1967 (ICSU/IUGG-WMO 1967) spelled out the broad outlines of the experiment and set down first estimates of the observations that would be required. These provided the basis for a program of observing systems design and numerical experimentation (COSPAR Working Group VI 1969, Bengtsson 1975). The GARP Basic Data Set Project of 1969-70 (Phillpot et al. 1971, Lamond et al. 1972, Thompson 1972) represented a first attempt to assemble a global data set approximating the FGGE requirements as a basis for more refined numerical experimentation.

Determination of the observational requirements for FGGE has involved a particularly intensive program of numerical experimentation. Basically it has been necessary to examine two questions:

1. What accuracy is required in describing the initial state of the atmosphere to permit prediction of the future state with useful skill for extended time periods?

2. What data network when employed with an effective analysis system will permit specification of the initial state to the required accuracy?

The various parameters that describe the large-scale state of the atmosphere are dynamically coupled and some appear to be more critical than others that may - in principle - be inferred. However, while certain trade-offs between parameters may be allowed for in specifying the data requirements for the Experiment, it has been continually borne in mind that a modest degree of redundancy must be retained if the FGGE data set is to be useful in guiding the design of a cost-effective global observing system for operational purposes.

The various diagnostic studies and observing system simulation experiments over the past decade have led to the following general conclusions (World Meteorological Organization 1977a):

- for extended prediction over any portion of the globe, data for the complete global atmosphere are required;
- because of the weak coupling between mass and motion in the tropics, particularly complete observations are there required;
- in order to sample adequately the behaviour of the atmosphere in different seasonal regimes, at least a year of data is required.
Figure 3 shows the presently planned time schedule for the Experiment eventually arrived at in the light of a host of scientific, organisational, and logistic considerations. Because of the enormous expense of maintaining a complete range of observing systems for an entire year, it was decided to concentrate the observational effort in two Special Observing Periods each of about 60 days in January-February and May-June 1979. The Special Observing Periods (known as SOP-I and SOP-II) each have, in turn, a core period of about 30 days of intensive observation. They will coincide with Regional GARP Experiments being mounted in connection with the monsoons of Asia (MONEX) and West Africa (WAMEX) and atmospheric processes in the polar regions (POLEX).

The observational requirements for the Global Weather Experiment as determined by the Joint Organizing Committee are summarised in Table 1. For the equatorial tropics (10°N to 10°S) the resolution requirements have been defined separately for 'active' and 'inactive' regions, which differ from season to season as shown in Fig 4. Figure 5 depicts schematically, for the Australian sector, the kind of network density that is implied by the statement of requirements in Table 1 and compares, in the right hand portion of the figure, an estimate of the present number of good World Weather Watch radiosonde stations in ten-degree latitude bands between 75°N and 75°S with the implied requirements for FGGE.

Although the numbers of World Weather Watch stations broadly meet FGGE requirements in the middle latitudes of the northern hemisphere, most of the stations are over the continents and there still exist major data gaps over the oceans. It is, however, abundantly clear from Fig 5 that, if the FGGE goals are to be met, a major observational effort must be mounted in the tropics and the southern hemisphere.

THE FGGE COMPOSITE OBSERVING SYSTEM

Early in the planning of FGGE, it became clear not only that the conventional surface-based observing network of the World Weather Watch could not provide the necessary data but that, indeed, no single observing system would be capable of providing all the data needed to meet the goals of the Experiment. Accordingly, much of the planning effort of the last ten years has been directed to the design of a composite observing system that would build upon, and supplement, for the period of the Experiment, the basic world-wide observing system developing under the World Weather Watch.

The Composite Observing System for FGGE is depicted schematically in Fig 6. It includes the following elements:

1. The Basic Observing System, which will operate throughout the entire 12 months of the Operational Year and continue after the end of the Experiment:
   - the WNW surface-based network (surface and upper air stations, ships, and aircraft),
   - geostationary satellites (provided by the European Space Agency, Japan, and the United States),
   - polar-orbiting satellites (provided by the USSR and the United States).

2. Special Observing Systems designed to fill the gaps in the Basic Observing System. Because of the high cost, most will operate only during the Special Observing Periods. They consist of:
   - supplemental World Weather Watch land stations established especially for FGGE to improve the sparse upper air network in certain regions,
The observational phase of the global weather experiment

**Build-up Year**

Final test of:
- Special Observing Systems
- Data Collection and Processing System

**Operational Year**

12 months of intensive global observations

Special Observing Periods

- Special Obs. Period I
  - Period of Intensive Observation
  - Jan 5, Feb 15, Mar 13, Apr 5
- Special Obs. Period II
  - Period of Intensive Observation
  - May 1, Jun 10, Jun 8, Jun 30

Fig 3 The time schedule for the Observational Phase of the Global Weather Experiment involving:

1. the Build-Up Year, which began on 1 December 1977 and during which new observation, communication, and data processing systems are progressively being brought into operation and Special Observing Systems tested;

2. the Operational Year, lasting for twelve months from 1 December 1978. During this period the basic observing and data processing systems will be in full operation;

3. two Special Observing Periods (SOPs) in January–February and May–June 1979 during which the various Special Observing Systems for the tropics and the southern hemisphere will be brought into operation;

4. periods of Intensive Observations in the central thirty days of each SOP during which all systems will be scheduled to operate simultaneously and at peak effectiveness.
Fig 4  Definition of the active (shaded) and inactive regions of the equatorial tropics during SOP-I (January-February 1979, upper) and SOP-II (May-June 1979, lower).
Fig 5 A schematic representation of the data requirements for FGGE (left) and a comparison with the present observational network (right). The array of dots in the earth-sector map on the left represents the approximate density of observation points from which surface measurements and vertical profiles of temperature, humidity and wind would be required to meet the specified data requirements (Table 1). The right hand portion of the diagram compares the corresponding number of observation points in ten-degree latitude bands with the numbers of good radiosonde stations available from the WWW upper air network.
Table 1. Data requirements for the Global Weather Experiment

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Coverage</th>
<th>Horizontal resolution</th>
<th>Number of levels in troposphere</th>
<th>Number of levels in stratosphere</th>
<th>Number per day</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind (U,V)</td>
<td>Middle and high latitudes</td>
<td>500 km</td>
<td>4</td>
<td>3</td>
<td>2*</td>
<td>±3 ms⁻¹</td>
</tr>
<tr>
<td></td>
<td>Equatorial tropics:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Troposphere (active regions)</td>
<td>350 or 500</td>
<td>5</td>
<td>-</td>
<td>1 or 2</td>
<td>±2 ms⁻¹</td>
</tr>
<tr>
<td></td>
<td>Troposphere (inactive regions)</td>
<td>500 or 700</td>
<td>5</td>
<td>-</td>
<td>1 or 2</td>
<td>±2 ms⁻¹</td>
</tr>
<tr>
<td></td>
<td>Stratosphere</td>
<td>4000 km</td>
<td>-</td>
<td>3</td>
<td>1</td>
<td>±2 ms⁻¹</td>
</tr>
<tr>
<td>Temperature (T)</td>
<td>Global</td>
<td>500 km</td>
<td>4</td>
<td>3</td>
<td>2*</td>
<td>±1°C</td>
</tr>
<tr>
<td>Relative humidity (RH)</td>
<td>Global</td>
<td>500 km</td>
<td>2</td>
<td>-</td>
<td>2*</td>
<td>±30%</td>
</tr>
<tr>
<td>Sea surface temperature (Tₛ)</td>
<td>Global</td>
<td>500 km</td>
<td>-</td>
<td>-</td>
<td>3-day average</td>
<td>±0.5°C</td>
</tr>
<tr>
<td>Surface pressure (Pₛ)</td>
<td>Global</td>
<td>500 km</td>
<td>-</td>
<td>-</td>
<td>2*</td>
<td>±1 mb</td>
</tr>
</tbody>
</table>

* Two desired, at least one required.
Tropical Wind Observing Ships (TWOS) to be equipped with upper air balloon sounding equipment for deployment over the tropical oceans,

an Aircraft Dropwindsonde System consisting of long-range aircraft deploying parachute sondes over the tropical oceans,

a Southern Hemisphere Drifting Buoy System consisting of a fleet of drifting buoys between latitudes 20°S and 65°S measuring sea surface temperature and atmospheric pressure.

3. Other observing systems that, while not specifically provided for FGGE, will contribute to the observational network. These include:

- research satellites such as the United States SEASAT and Nimbus-G,

- a Special Aircraft Data Collection program to retrieve meteorological data from commercial aircraft equipped with inertial navigation systems,

- a number of special oceanographic programs that will coincide with FGGE.

The individual components of the Composite Observing System are described in detail in the various volumes of the Implementation/Operations plan now being prepared for publication by the World Meteorological Organization.

The World Weather Watch surface-based network

The surface-based component of the World Weather Watch Global Observing System (GOS) will provide the foundation for the FGGE observational effort. At present it consists of:

- more than 9200 stations making surface observations for international exchange,

- nearly one thousand stations making upper air observations,

- nine fixed ocean weather stations,

- approximately 7400 ships making voluntary surface observations,

- 55 mobile ships making upper air observations,

- an average of 1600 aircraft reports per day.

Figure 7 illustrates the present coverage of upper air observing stations included in the GOS Regional Basic Synoptic Networks. Observational data from the surface and upper air networks and from ships and aircraft are currently exchanged in real time over the WWW Global Telecommunication System (GTS) shown schematically in Fig 8. Under the World Weather Watch, the data are then processed within the Global Data Processing System (GDPS) consisting of a network of World (Melbourne, Moscow, Washington), Regional, and National Meteorological Centres.

Geostationary satellites

The early planning for FGGE (e.g., COSPAR Working Group VI 1969) envisaged a system of four geostationary satellites equally spaced around the equator and providing visible and infrared scanning (and associated wind determination by cloud tracking)
Fig 6 The Composite Observing System for FGGE. The various components of the observing system additional to the routine surface-based network are shown schematically in this cross-sectional representation from the North (left) to the South Pole.
Fig 7 Coverage of upper air observing stations included in the Regional Basic Synoptic Networks of the WWW Global Observing System. Each dot represents a station providing one or more conventional (balloon) upper air soundings of wind and/or temperature daily.
Fig 8  The Global Telecommunication System (GTS) of the World Weather Watch.
and data relay facilities. Subsequently agreement was reached on plans for a five-satellite system as follows (Fig 9):

<table>
<thead>
<tr>
<th>Location</th>
<th>Satellite</th>
<th>Operator</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>METEOSAT</td>
<td>European Space Agency (ESA)</td>
</tr>
<tr>
<td>70°E</td>
<td>GOMS</td>
<td>USSR</td>
</tr>
<tr>
<td>140°E</td>
<td>GMS (Himawari)</td>
<td>Japan</td>
</tr>
<tr>
<td>135°W</td>
<td>SMS-II</td>
<td>USA</td>
</tr>
<tr>
<td>75°W</td>
<td>GOES-II</td>
<td>USA</td>
</tr>
</tbody>
</table>

By late 1977 all spacecraft except the USSR GOMS were in orbit. Owing to an expected slippage of the GOMS launch date to 1979, a contingency plan was developed under which the Indian Ocean gap would be filled with a standby US spacecraft communicating with a ground station operated by the European Space Agency.

Figure 10 shows one of the first earth disc images available from the Japanese geostationary satellite following its launch in July 1977. All five satellites will provide both visible and infrared imagery, but with some variations in imaging frequency and resolution. Wind vectors will be derived 2 to 4 times daily out to about 50° from the satellite sub-point by measuring the displacement of low, middle, and high clouds using sequential pictures half an hour apart. The infrared radiation measurements will also be used to provide information on sea surface temperature, cloud cover, and cloud top temperatures.

The geostationary satellite network, although planned and implemented under the stimulus of the FGGE, seems likely to continue into the 1980s as a basic component of the World Weather Watch. The USSR GOMS should be in orbit by 1980, the USA plans to maintain its two satellites as an operational system, METEOSAT-2 is planned for launch in 1980, and Japan expects to launch GMS-II by mid-1981.

Polar-orbiting satellites

Polar-orbiting meteorological satellites have been an integral part of the World Weather Watch Global Observing System for over a decade. During that period the availability of cloud imagery from orbiting US satellites has largely revolutionised synoptic analysis over the ocean areas of the southern hemisphere and substantial progress has been made with the use of satellite-sensed vertical profiles of temperature and humidity. For the FGGE, two new-generation satellite systems will be employed.

The USA will provide a two-satellite system consisting of TIROS-N (prototype) and NOAA-A (operational) spacecraft (Hussey 1977). The two satellites are planned for launch into near-polar sun-synchronous orbits (inclination 98.7°, period 101.58 minutes) at altitudes of approximately 870 km (TIROS-N) and 833 km (NOAA-A) with ascending equatorial crossing times around 1500 and 1930 Local Time respectively (Fig 11). Both satellites will carry:

1. a TIROS Operational Vertical Sounder (TOVS), which will measure upwelling radiation at a number of wavelengths in the infrared and microwave as a basis for deriving temperature profiles from the surface to about 1 mb with an accuracy of 1 to 1.5°C and a horizontal resolution of about 250 km;

2. an Advanced Very High Resolution Radiometer (AVHRR), which will provide imagery at four visible and infrared wavelengths (0.55 to 0.90 μm, 0.725 to 1.10 μm, 3.55 to 3.93 μm, 10.5 to 11.5 μm) at a resolution of 1 km;
Fig 9  The system of geostationary meteorological satellites for FGGE.
Fig 10. A full earth disc view (visible channel) from the Japanese Geostationary Meteorological Satellite on 8 September 1977 with superposed surface (bottom) and 200 mb (top) circulation patterns adapted from operational analyses produced by the Darwin and Melbourne Regional Meteorological Centres.
Fig 11  Schematic representation of the TIROS-N polar-orbiting satellite system for FGGE. The sub-orbital tracks shown in the lower part of the diagram indicate the approximate coverage of the earth during a six-hour period centred on 0000 GMT.
3. a French ARGOS Data Collection and Platform Location System (DCPLS), which will receive and store data from constant level balloons, drifting buoys, and other observing platforms for relay to ground receiving stations.

The USSR will provide an improved METEOR system involving two (or three) satellites in circular orbit at a height of about 1000 km and with an orbital inclination of 81°. The METEOR system will provide television and multi-wavelength infrared imagery.

Supplemental World Weather Watch land stations

A number of WMO Members have made arrangements for the temporary installation of surface and upper-air observing stations in otherwise data-sparse areas to supplement the normal Regional Basic Synoptic Networks during the FGGE Operational Year or, at least, during the Special Observing Periods. As an example, the Australian Bureau of Meteorology has advised WMO that it hopes to provide a temporary wind-finding radar at Thursday Island for use during the FGGE Special Observing Periods.

Tropical Wind Observing Ships

Figure 12 summarises the concept of operation of the Tropical Wind Observing Ships (TWOS) system, one of three special observing systems designed to provide the necessary information on the detailed vertical wind structure in the equatorial tropics.

Approximately fifty ships are expected to be deployed in the active regions between 10°N and 10°S during the two Special Observing Periods. Some will employ conventional radiosondes tracked by stable-platform shipboard radar or radio direction-finding equipment. Others will make use of the world-wide Omega navigation system to derive vertical wind profiles through use of a special FGGE Navaid Sounding System.

The FGGE Navaid Sounding System has been made possible through a Special Voluntary Fund established by the WMO Executive Committee. The system employs special balloon-borne radiosondes that receive and retransmit signals from the world-wide Omega navigation system during their ascent. The retransmitted signals are received by equipment on board the launching ship. The system may be utilised in either a basic configuration in which the data are merely recorded on board on magnetic cassettes for later processing or as a complete system in which processing takes place on board and the data may be relayed, in real time, either by satellite or conventional communication links to the Global Telecommunication System. The system will produce twice-daily vertical profiles of temperature, pressure, humidity, and wind from the surface to approximately 10 mb. The wind profile is determined from position changes of the ascending sonde as detected through the Omega system. The propagation patterns of synchronised Omega signals undergo diurnal variations such that the preferred time for making wind soundings will be around local noon and local midnight.

Aircraft Dropwindsondes

The concept of operation of the Aircraft Dropwindsonde System is depicted in Fig 13. The dropwindsonde program aims at providing vertical wind profiles and temperature, pressure, and humidity information over the tropical oceans in areas where there are no island stations and no Tropical Wind Observing Ships during the Special Observing Periods. The program will operate for the central 30 days of each Special Observing Period and provide a total of more than 2½ million km of flight track information.
Fig 12 Concept of operation of the Tropical Wind Observing Ships (TWOS) system showing also the location of stations of the Omega network and probable TWOS locations during the first Special Observing Period.
The Dropwindsonde System will be provided by the USA. A fleet of long-range aircraft operating out of Acapulco (Mexico), Honolulu (Hawaii), Diego Garcia, and Recife (Brazil) will fly one sortie per day along tracks such as those shown in the lower part of Fig 13. At approximately 350 km intervals along the tracks, the aircraft will release small instrument packages containing Omega signal receivers/retransmitters along with pressure, temperature, and humidity sensors. As the small parachute sondes descend at about 300 metres per minute they receive, and retransmit to the deploying aircraft, Omega signals at 13.6 kHz from all Omega stations within reception range along with signals derived from the sensors. Position determination and hence horizontal velocity of the sonde as it drifts along with the wind is based on measurement of phase differences in the received Omega signals from the various transmitting stations. On board the aircraft, the signals will be recorded and processed into standard meteorological messages giving wind, temperature, geopotential, and humidity at standard and significant levels (TEMP DROP code) for HF radio transmission to a ground station, if one is within range, and insertion into the WWW Global Telecommunication System.

Data from all drops will also be recorded onboard on magnetic tape. The tapes will be forwarded to the Aircraft Dropwindsonde Data Centre (the US National Centre for Atmospheric Research) for delayed processing into Level II-b parameters (see later) and subsequent transmission to the Level II-b Space-based and Special Observing System Data Centre in Sweden. The data set will consist of flight level data (from the aircraft system), wind profiles from about 1000 metres below the aircraft down to 300 metres above the sea surface, and thermodynamic data from about 500 metres below the aircraft to the surface.

Day to day coordination and flight track selection will involve two-way exchange of information between the FGGE Operations Centre in Geneva, the Aircraft Dropwindsonde Coordinating Centre (ADCC) at NOAA Headquarters in Rockville, Maryland, and the four Operating Locations (OL) at Acapulco, Honolulu, Diego Garcia, and Recife. Automated flight planning will be provided by the US Airforce Global Weather Central based on advice of track selection from the ADCC. The aircraft will, in general, be flown in a maximum range, cruise, climb configuration with take-off scheduled to place the aircraft at mid-point of the planned track around local noon. Cruise altitude will range from 8000 metres (WC-130 aircraft, initial drop) to 14 000 metres (WC-135 and C141 aircraft, final drop). Cancellations, changes, or modifications to the track selected by the ADCC may be made by the Director at each Operating Location in the light of changes in the operational status of the aircraft, observing systems, personnel, current information on meteorological conditions along the selected track, and to ensure flight safety.

Tropical Constant Level Balloons

The concept of operation of the Tropical Constant Level Balloon System (TCLBS) is depicted in Fig 14. Its purpose is to fill in the gaps in the TWOS and island station network over the tropical oceans in the high troposphere above the operating altitude of the dropwindsonde aircraft.

The Tropical Constant Level Balloon System is being provided as a joint contribution by the USA and France. It consists of three basic sub-systems: the balloon platform and sensors; the TIROS-N ARGOS Data Collection and Platform Location System (DCPLS); and the ground data processing centres. The balloon is a 4.15 metre diameter helium-filled superpressure sphere with an 80 metre long flight train consisting of a solar panel to recharge batteries for night-time operation, a parachute to slow the balloon descent on cut-down, an antenna, data information package, and temperature sensor. The balloons are designed to float on a constant density surface of 0.225 kg m$^{-3}$ (i.e. at approximately 15 km), above the normal cruise altitudes of the highest subsonic transport aircraft and below the cruise altitude of supersonic aircraft. Automatic cut-down occurs if the balloons descend below 14 km or move too far out of the tropics into the northern hemisphere. As the TIROS-N or NOAA-A sat-
Fig 13 Concept of operations of the Aircraft Dropwindsonde System showing possible aircraft flight tracks to be flown daily during the Special Observing Periods.
Fig 14 Concept of operation of the Tropical Constant Level Balloon System showing a possible distribution of balloons during the Special Observing Periods.
ellite passes within line of sight of a balloon, the onboard ARGOS DCPLS receives signals from the balloon that provide the temperature at balloon flight level and the information necessary to derive balloon position. The data are stored on board for read-out at one of three ground telemetry stations (Wallops Island, Virginia; Gilmore Creek, Alaska; Lannion, France) and relay to the US National Environmental Satellite Service (NESS). At NESS the ARGOS data are separated from the other satellite data and relayed in real time to the ARGOS Data Processing Centre at the Centre National d'Etudes Spatiales (CNES) in Toulouse, France. Processing is performed at Toulouse to compute balloon locations by differential Doppler techniques and balloon speeds (based on positions determined from successive satellite passes) as well as temperature. Selected data are inserted into the WWW Global Telecommunication System and complete data tapes passed to the TCLBS Data Centre at the US National Center for Atmospheric Research for further processing and forwarding to the Space-based and Special Observing System Data Centre in Sweden.

Coordination of balloon launch and control of the overall system will be provided by the TCLBS Control Center at NOAA Headquarters in conjunction with the FGGE Operations Centre in Geneva. The 320 balloons will be launched from Canton Island in the Pacific and Ascension Island in the Atlantic according to a schedule that aims at providing a maximum number of platforms as uniformly distributed as possible within the deep tropics (10°N to 10°S) during the central 30 days of the two Special Observing Periods. About 100 balloons are expected to be adrift during each Special Observing Period, each providing at least four daily measurements of wind (1.5 ms⁻¹ r.m.s. error) and temperature (0.7°C). Position errors are estimated at 5 km r.m.s. and pressure errors at 3 mb r.m.s.

Southern Hemisphere Drifting Buoy System

The concept of operation of the Southern Hemisphere Drifting Buoy System is depicted in Fig 15. The purpose of this system is to provide a network of essential surface pressure and sea surface temperature measurements for use, in conjunction with satellite temperature soundings, to infer vertical wind and temperature profiles over the normally data sparse oceans of the southern hemisphere. Until mid 1976, plans were proceeding for a US-France-Iran-sponsored southern hemisphere constant level balloon system to supplement the drifting buoys but lack of adequate indications of additional support, particularly from southern hemisphere countries, led to cancellation of the proposed balloon program. The buoy system is thus critical to the performance of the composite observing system in the southern hemisphere.

The Southern Hemisphere Drifting Buoy System is a joint contribution of several nations coordinated through an international Committee of Participants for the Southern Hemisphere Drifting Buoy System for FGGE. The main contributions are by the USA and France (satellite and data processing systems and provision and deployment of buoys - US about 50, France about 40), Canada (deployment planning and provision of about 80 buoys), Australia (operational data quality monitoring and about 50 buoys), Norway (55 buoys), New Zealand (10 buoys), the United Kingdom (9 buoys), Argentina (deployment), and Chile (deployment). In total about 300 buoys will be deployed in the latitude band 20 to 65°S providing an average horizontal resolution of approximately 1000 km.

A number of different buoy designs will be employed but the majority will be of the spar type typified by the Australian prototype shown schematically in Fig 15. All will measure surface pressure and sea surface temperature and a few will measure additional parameters. The buoys will carry small battery-powered transmitters that will transmit buoy identification, pressure and temperature sensor information, and relevant engineering parameters at intervals of 40 to 60 seconds. The data will be collected, on a random access basis, by the French ARGOS Data Collection and Platform Location System (DCPLS) on board the US TIROS-N and NOAA-A satellites. The data will be stored on board the satellite and read out as soon as the satellite comes within range of a ground receiving station. The data will then be passed via the US National
Fig 15  Concept of operation of the Southern Hemisphere Drifting Buoy System showing a possible distribution of drifting buoys in the southern oceans during the Special Observing Periods.
Environmental Satellite Service (NESS) to the Data Processing and Control Centre at Toulouse in France. At Toulouse the data will be processed and coded messages containing buoy location, pressure, and sea temperature inserted into the Global Telecommunication System within a matter of hours. At least four observations per day should be available from each buoy. The data will also be processed in a delayed mode to provide complete quality-controlled buoy data sets on magnetic tape for forwarding to the Space-based and Special Observing System Data Centre in Sweden. Buoy location is based on successive measurements of the Doppler shift in the carrier frequency of the buoy transmission as observed by the satellite.

Other observing systems

In addition to the various special observing systems to be implemented specifically for the FGGE, there will be a number of other atmospheric and ocean observing facilities and programs that will contribute to the data collection effort for the Experiment.

Two US environmental research satellites are expected to be aloft during FGGE. The National Aeronautics and Space Administration (NASA) expects to launch both the NIMBUS-G and SEASAT satellites during 1978. NIMBUS-G, in near-polar sun-synchronous orbit at a height of 955 km will cross the equator around local noon and local midnight and provide data on earth radiation budget parameters, ozone distribution and amount, and parameters such as sea ice coverage, sea surface temperature, sea surface wind speeds, total atmospheric water vapour, and rainfall rate over the oceans. SEASAT is planned to fly in a non-synchronous orbit at a height of 795 km with an orbital inclination of 108° retrograde. It will provide observations of sea surface wind speed and direction, sea ice coverage, sea surface temperature, total atmospheric water vapour, and rainfall rate over the oceans. Approximately 36 hours will be required to obtain 95 per cent coverage by SEASAT over the earth's surface between 75°N and 75°S. The data from both satellites will be processed by NASA and provided on magnetic tape in international data exchange formats to the Space-based and Special Observing System Data Centre in Sweden.

A special aircraft data collection effort being arranged to coincide with FGGE is expected to provide a substantial amount of additional data for the upper troposphere in both hemispheres. The concept of operation of the special aircraft data collection scheme is depicted in Fig. 16. Arrangements will be made for about eighty wide-bodied jet aircraft equipped with Aircraft Integrated Data Systems (AIDS) to record, on small magnetic tape cassettes, a range of meteorological parameters such as temperature, pressure, and winds determined from the aircraft Inertial Navigation System. The cassettes containing data for accurately known positions at intervals of about 200 km along the flight track will be removed from the aircraft on landing and mailed to a Special Aircraft Data Centre in the Netherlands for processing. Australia, Denmark, Indonesia, The Netherlands, Philippines, Switzerland, Thailand, the UK, the USA, and Venezuela will be among the countries whose national air carriers will participate in the program, which will last throughout the FGGE Operational Year. In addition to the 80-odd aircraft providing data in a delayed mode, a further 20 or so wide-bodied jets (B-747 and DC-10 aircraft) are expected to carry prototype Aircraft to Satellite Data Relay (ASDR) equipment packages. These will automatically transmit position and meteorological data via the geostationary satellite data collection system for insertion into the Global Telecommunication System in real time.

A number of other observational and research programs and, in particular, specialised oceanographic data collection activities, will contribute to the FGGE data gathering effort. The Federal Republic of Germany will operate a collection centre for operational oceanographic data and the USA will assume responsibility for collection of specialised oceanographic data in a delayed mode.
Fig 16 Concept of operation of the special aircraft data collection that will coincide with FGGE. The bottom portion of the diagram shows some of the main air routes from which data are expected to be collected during the FGGE operational year.
THE FGGE DATA MANAGEMENT SCHEME

For the purposes of design of a data collection and processing system for FGGE, it was found convenient to distinguish between three different data levels known as Level I (primary data), Level II (meteorological parameters), and Level III (initial state parameters) and to further categorise Level II and III data according to whether they are produced in an operational (a) or delayed (b) mode. The definition of data types is summarised in Table 2. The end-product of the observational phase of FGGE will be the complete, checked global sets of meteorological parameters from the various observing systems (the Level II-b data) and the internally consistent global analyses produced from them (the Level III-b data).

Table 2 Definition of data levels

<table>
<thead>
<tr>
<th></th>
<th>a</th>
<th>b</th>
<th>c</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level I</td>
<td>(primary data)</td>
<td>(global experiment data)</td>
<td>(special data for climatic investigations)</td>
</tr>
<tr>
<td></td>
<td>These in general are instrument readings expressed in appropriate physical units and referred to earth coordinates. Examples are radiances or positions of constant level balloons but not raw telemetry signals. Level I data still require conversion to meteorological parameters.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level II</td>
<td>(meteorological parameters)</td>
<td>Global Experiment Research Data Set collected with a delayed cut-off through a special FGGE collection scheme.</td>
<td>Data for climatic investigations collected in a delayed mode.</td>
</tr>
<tr>
<td></td>
<td>Data collected through the Global Telecommunication System within the operational cut-off.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level III</td>
<td>(initial state parameters)</td>
<td>Operational analyses obtained from Level II-a data by the World Meteorological Centres.</td>
<td>Global Experiment analyses obtained from Level II-b data in non-real time by special FGGE analysis centres.</td>
</tr>
</tbody>
</table>

The overall data flow during FGGE is depicted in Fig 17. It can be seen that there are two parallel data management schemes - that shown on the left, operating in real-time through the Global Telecommunication System (GTS) and the World Meteorological Centres of the World Weather Watch and producing operational Level II-a and Level III-a data sets; and that shown on the right functioning in a delayed mode and involving special data collection procedures to supplement the GTS and special data analysis centres to produce the Global Experiment Level II-b and Level III-b data sets for delivery to the ICSU World Data Centres A and B.

Generation of WWW data sets

Some of the detail of the operational data flow depicted in the left half of Fig 17 is shown in Fig 18. It is intended that as much as possible of the data from all the observing systems operating during the Experiment should be collected in the World Meteorological Centres within hours of observation time and be used for operational purposes. A key factor in the success of the operational data collection
Fig 17 The overall data flow during FGGE involving parallel streams in the operational (left) and delayed (right) modes. Note the dependence of the Level II-b collection scheme on the results of the initial real-time collection through the Global Telecommunications System.
will be the performance of the Global Telecommunication System (Fig 8) and, in particular, the flow of data on its Main Trunk Circuit linking the three World Meteorological Centres.

Most of the data processing in the World Meteorological Centres in support of FGGE will be conducted as part of their routine operations in support of national and WWW commitments although it is expected that, for the period of the Experiment, the WMCs will extend their operational cut-off times to some 10 to 24 hours after observation time (World Meteorological Organization, 1977b).

Level II-a data set preparation at the WMCs will involve the transformation of coded observations received over the Global Telecommunication System to checked meteorological data archived in agreed international format on magnetic tape. Level II-a data sets will be produced for every day of FGGE. The data sets themselves will be held in the WMC archives and data inventories will be provided to the ICSU World Data Centres A and B.

Level III-a data sets will be produced by the WMCs twice each day for the FGGE period. They will be based on the Level II-a data sets and will be produced in an operational mode using the particular WMC's data assimilation/analysis model. Full Level III-a data sets in agreed international format will be passed with all necessary documentation to the ICSU World Data Centres and will also be stored in WMC archives.

Generation of Global Experiment data sets

A significant amount of the observational data, especially those from the various special observing systems, will not be received through the Global Telecommunication System before the operational cut-off of the World Meteorological Centres. In particular, the communication and data processing schemes for the various satellites and special observing systems may not operate at all times and communication blackouts may delay receipt of data from key areas such as the Antarctic. Thus the generation of the definitive Global Experiment (II-b and III-b) data sets is based on the operation of a special delayed Level II-b Collection Scheme and subsequent analysis by special Level III-b Data Producers, which will be research organisations possessing facilities compatible with the WMCs.

The delayed data flow during FGGE leading to the generation of the definitive Level II-b and Level III-b data sets is depicted in Fig 19. The Level II-b collection scheme is based on the operation of a number of specialised collection centres feeding checked, sorted data tapes into two main centres in the USSR (surface-based observations) and Sweden (space-based and special observing systems).

Area Sub-centres in Japan, the UK, the US and the USSR have assumed responsibility for the collection, processing, and quality control of land surface and upper air reports (including those from ocean weather stations) and for the real-time collection of mobile ship and aircraft reports within designated areas as shown in Fig 20. The area sub-centres will collect as much data as possible in real-time over the Global Telecommunication System and will subsequently follow up by mail, telex, or other means to obtain missing or corrupt data from the responsible National Meteorological Centres. It is intended that the delayed collection by the Area Sub-centres be completed within 2 to 3 months of observation time. The processed, checked reports in international format on magnetic tape will then be delivered to the Level II-b Surface-based Data Centre in the USSR.

The Operational Satellite Data Producers of Japan, the European Space Agency, the US, and the USSR have agreed to assemble, on magnetic tape, complete sets of cloud displacement winds, vertical temperature and humidity sounding data, and sea surface temperatures for delivery to the Level II-b Space-based and Special Observing System Data Centre in Sweden within approximately two months of observation time.
Fig 18 The operational data flow during FGGE leading to generation of the World Weather Watch (Level II-a and Level III-a) data sets by the World Meteorological Centres in Melbourne, Moscow, and Washington.
Fig 19  The delayed data flow during FGGE leading to the generation of the definitive Global Experiment (Level II-b and Level III-b) data sets and their availability to users through the ICSU World Data Centres.
Fig 20  Areas of responsibility for the four Area Sub-Centres for collection of real-time and delayed land surface and upper air reports during FGGE.
Specialised data centres will be operated by a number of countries and organisations as follows:

- The **Mobile Ship Data Centre** (Federal Republic of Germany) will collect and assemble mobile ship data in non-real-time on the basis of punched cards and magnetic tapes received from WMO Members and forward these to the USSR Surface-based Data Centre within 3 to 4 months of observation time.

- The **Tropical Wind Observing Ship (Radar) Data Centre** (USSR) will collect and quality control upper air soundings from radar-equipped ships and forward these in international format to the Level II-b Surface-based Data Centre within 4 months of observation time.

- The **Tropical Wind Observing Ship (Navaid) Data Centre** (Finland) will collect and quality control upper air soundings from all Tropical Wind Observing Ships equipped with the Navaid system and forward these in international format to the Level II-b Space-based and Special Observing System Data Centre in Sweden within 4 months of observation time.

- The **Aircraft Dropwindsonde Data Center** (USA) will collect and process the magnetic tapes from the four Operating Locations of the Aircraft Dropwindsonde System and deliver the data set to the Level II-b Space-based and Special Observing System Data Centre in Sweden within 3 months of observation time.

- The **Tropical Constant Level Balloon Data Center** (USA) will process the constant level balloon data collected through the French ARGOS system on board TIROS-N and NOAA-A and deliver tapes containing the checked data to the Space-based and Special Observing System Data Centre in Sweden within 2 months of observation time.

- The **Drifting Buoy Data Centre** (France) will collect, process, and quality control data from the southern hemisphere drifting buoys (and some other buoys in the northern hemisphere) received through the ARGOS system and deliver tapes containing the checked data to the Space-based and Special Observing System Data Centre in Sweden within 2 months of observation time.

- The organisations (primarily NASA) operating experimental satellites will provide magnetic tapes containing data sets (ocean surface wind, total water vapour, stratospheric temperature profiles etc.) to the Space-based and Special Observing System Data Centre in Sweden within 3 months of observation time.

- The **Specialised Oceanographic Data Centres** (Federal Republic of Germany for operational data; USA for non-operational data) will forward magnetic tapes containing bathythermograph data and temperature, salinity, and current profiles collected through the WMO-IOC (International Oceanographic Commission) ICOSSS program, to the Space-based and Special Observing System Data Centre in Sweden within about 3 months of observation time.

- The **Special Aircraft Data Centre** (The Netherlands) will collect and process observations in a delayed mode from aircraft logs and from the magnetic cassettes taken from AIDS-equipped aircraft and forward the data set to the Space-based and Special Observing System Data Centre in Sweden within 3 months of observation time.
On receipt of individual data sets from the area sub-centres and specialised data centres, the two main Level II-b Data Centres in the USSR and Sweden will proceed to merge the various data types, eliminating duplicate reports etc., and then exchange their data sets so that eventually each will have a complete data set ready for delivery to the ICSU World Data Centres A and B. It is intended that the data will be exchanged in sub-sets of 10 days with all the data for any given 10-day period being available to the World Data Centres approximately 6 months after the last day of the period. Each 10-day period is expected to require about fourteen magnetic tapes during the Special Observing Periods and seven tapes at other times. The total FGGE Level II-b data set is thus expected to fill approximately 340 magnetic tapes.

Two Level III-b Data Producers (the European Centre for Medium Range Weather Forecasts and the Geophysical Fluid Dynamics Laboratory (Princeton, USA)) will receive Level II-b data sets direct from the Level II-b Data Centre in Sweden. Other Level III-b Data Producers will obtain their data sets from World Data Centres A or B. The role of the Level III-b Data Producers will be to produce global analyses using advanced data assimilation schemes and to have their completed Level III-b data sets available for archiving at the World Data Centres within two years of the end of the FGGE Operational Year. It is intended that the Level III-b data sets will include fields of:

- geopotential
- sea level pressure
- horizontal wind components
- vertical motion (derived)
- temperature
- sea surface temperature
- relative humidity.

Other analyses, including cloud and snow cover, precipitation, heat fluxes, and so on, will also be prepared. The required horizontal grid spacing is 250 km with ten levels in the vertical. Analyses will be prepared four times daily during the Special Observing Periods and twice daily during the remainder of the Operational Year.

Availability of data sets for research

Although a certain amount of experimentation and research will be undertaken concurrently with the observational phase of FGGE, the central task of the experiment is to produce adequate data sets for subsequent research.

The primary source of FGGE data sets for research will be the two ICSU World Data Centres for Meteorology. The two centres will hold identical data sets to guard against the possibility of a complete loss of FGGE data in the event of a catastrophic destruction of a single centre. The two centres are:

World Data Centre A for Meteorology  World Data Centre B for Meteorology
National Climatic Center  Moscow 117296
Federal Building  Molodezhnaya 3
Asheville  USSR
North Carolina  USA  28801

The holdings of the centres will be as follows:

1. *Level I - primary data.* The World Data Centres will maintain inventories of polar orbiting satellite vertical sounder raw radiation data, geostationary satellite image data, and Special Observing Systems raw data. The data sets themselves will be
available from national archives. Photographic products from polar-orbiting satellites will probably be archived on microfilm in the World Data Centres.

2. Level II - meteorological parameters. For Level II-a data sets, only inventories will be archived in the World Data Centres with the data sets themselves available from World Meteorological Centre archives. World Data Centres will archive the Level II-b data sets.

3. Level III - initial state parameters. The World Data Centres will archive the three Level III-a data sets produced by the World Meteorological Centres in Melbourne (southern hemisphere only), Moscow, and Washington for the entire FGGE period. The World Data Centres will also archive the Level III-b data sets produced by the two main Level III-b Data Producers and other Level III-b data sets produced by approved organisations.

CONCLUSION

The Global Weather Experiment is a unique undertaking in the fields of science and international affairs. Night and day for a period of twelve months, a vast army of scientists, ships, and aircraft from many nations will be on station around the world arrayed, as in war, but 'against no enemy save man's ignorance of his planet' (Stever 1975). The planning for FGGE has opened up new frontiers in international cooperation in science - between nations, between disciplines, and between the governmental and non-governmental areas of science. Its execution will undoubtedly involve both successes and failures, but the world meteorological community has reason to feel confident that the concerted planning over recent years will have left few possibilities for serious failure.

It will not be easy to evaluate the success of the Experiment. It would be wrong to expect instantly improved forecasts because that is not what the immense data-gathering effort is about. The long, difficult research phase is still to come and we do not know what that will bring. But the achievement of FGGE will be to have laid the foundation for research which is now believed to have a good prospect of extending the useful range of weather forecasts out to 10 days or more within a decade.


